In summary, sufficient throughput can be achieved with necessary accuracy using a vector processor 410 applying integer math on 16-bit block-floating integers. Of course, in other embodiments, different block-floating sizes can be used depending on such criteria as the number of users, speed of the processors, and necessary accuracy of the symbol estimates, to name a few. Further, like methods and logic described can be used to generate other matrices (e.g., the gamma-matrix and the C-matrix) and to perform other calculations within the illustrated embodiment.

A further understanding of the operation of the illustrated and other embodiments of the invention may be attained by reference to (i) US Provisional Application Serial No. 60/275,846 filed March 14, 2001, entitled "Improved Wireless Communications Systems and Methods"; (ii) US Provisional Application Serial No. 60/289,600 filed May 7, 2001, entitled "Improved Wireless Communications Systems and Methods Using Long-Code Multi-User Detection" and (iii) US Provisional Application Serial Number. 60/295,060 filed June 1, 2001 entitled "Improved Wireless Communications Systems and Methods for a Communications Computer," the teachings all of which are incorporated herein by reference, and a copy of the latter of which may be filed herewith.

The above embodiments are presented for illustrative purposes only. Those skilled in the art will appreciate that various modifications can be made to these embodiments without departing from the scope of the present invention. For example, the processors could be of makes and manufactures and/or the boards can be of other physical designs, layouts or architectures. Moreover, the FPGAs and other logic devices can be software or vice versa. Moreover, it will be appreciated that while the illustrated embodiments decomposes physical user waveforms to virtual user waveforms, the mechanisms described herein can be applied, as well, without such decomposition, and that, accordingly, the terms "waveform" or "user waveform" should be treated as referring to either physical or virtual waveforms unless otherwise evident from context.

Therefore, in view of the foregoing, what we claim is:

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Load Balancing Computational Methods In A Short-code Spread-spectrum Communications System

1. A method of processing spread spectrum waveforms transmitted by a plurality of users of a spread spectrum system, comprising

distributing among a plurality of logic units parallel tasks each for computing a portion of a matrix indicative of cross correlations among the waveforms transmitted by the users,

executing with the plurality of logic units the distributed tasks.

2. The method of claim 1, wherein the step of distributing comprises partitioning computation of the cross-correlation matrix such that a computational load associated with a task distributed to one of said logic units is substantially equal to computational load associated with another task distributed to another logic unit.

3. The method of claim 2, further comprising generating detection statistics corresponding to symbols transmitted by the users and encoded in the waveforms as a function of the cross correlation matrix.

4. The method of claim 3, further comprising generating estimates of the symbols based on the detection statistics.

5. The method of claim 3, further comprising the step of defining a metric associated with each partition in accord with the relation:

$$B_i = A_i - A_{i-1}$$

wherein

A_i represents an area of a portion of the cross-correlation matrix corresponding to the i^{th} partition, and

i represents an index corresponding to the number of logic units.

6. The method of claim 5, further comprising the step of representing the cross-correlation matrix as a composition of a rectangular component and a triangular component.

7. The method of claim 6, wherein each area A_i includes a first portion corresponding to the rectangular component and a second portion corresponding to the triangular component of the cross-correlation matrix.

8. The method of claim 7, wherein the step of partitioning the matrix includes selecting the matrix associated with the partitions to be substantially equal.

9. The method of claim 6, wherein the cross-correlation matrix is computed as a composition of a first component that represents correlations among time lags and code sequences associated with the waveforms transmitted by the users and a second component that represents correlations among multipath signal amplitudes associated with the waveforms transmitted by the users.

10. A method of processing spread spectrum waveforms transmitted by a plurality of users of a spread spectrum system, comprising

partitioning computation of a matrix representing cross-correlations among the waveforms transmitted by the users in accord with a pre-defined metric,

distributing among a plurality of logic units parallel tasks each corresponding to one of said partitions for computing a portion of the matrix, and

executing with the plurality of logic units the distributed tasks.

11. The method of claim 10, further comprising assembling said computed portions to generate the cross-correlation matrix.

12. The method of claim 11, wherein the step of partitioning comprises defining the metric in accord with the relation:

$$B_i = A_i - A_{i-1}$$

wherein

A_i represents an area of a portion of the cross-correlation matrix corresponding to the i^{th} partition, and

i represents an index corresponding to the number of logic units.

13. The method of claim 12, further comprising the step of generating detection statistics corresponding to symbols transmitted by the users and encoded in said waveforms as a function of the cross-correlation matrix.

14. The method of claim 13, further comprising estimating the symbols based on said detection statistics.

15. The method of claim 14, further comprising representing the cross-correlation matrix as a composition of a first component that represents correlations among time lags and code sequences associated with the waveforms transmitted by the users and a second component that represents correlations among multipath signal amplitudes associated with the waveforms transmitted by the users.

16. The method of claim 15, further comprising the step of computing correlations among the code sequences associated with the respective users in accord with the relation:

$$\Gamma_{lk}[m] \equiv \frac{1}{2N_l} \sum_{n=0}^{N-1} c_l^*[n] \cdot c_k[n-m]$$

wherein

$\Gamma_{lk}[m]$ represents correlation between l and k user codes corresponding to a shift of m chips,

$c_l^*[n]$ represents complex conjugate of the code sequences associated with the l^{th} user,

$c_k[n-m]$ represents the code sequences associated with k^{th} user,

N represents the length of the code, and

N_l represent the number of non-zero length of the code.

17. The method of claim 16, further comprising the step of computing the first component of the cross correlation matrix as a matrix component (herein referred to as C matrix) in accord with the relation:

$$C_{lkqq'}[m'] = \sum_m g[mN_c + \tau] \cdot \Gamma_{lk}[m]$$

wherein

g is a pulse shape vector,

N_c is the number of samples per chip,

τ is a time lag, and

$\Gamma_{lk}[m]$ represents correlation between l and k user codes corresponding to a shift of m chips,

18. The method of claim 17, further comprising the step of computing the cross-correlation matrix (herein referred to as r matrix) in accord with the relation:

$$r_{lk}[m'] = \sum_{q=1}^{L}\sum_{q'=1}^{L} \mathrm{Re}\left\{\hat{a}_{lq}^{*}\, a_{kq'} \cdot C_{lkqq'}[m']\right\} = \mathrm{Re}\left\{a_l^H \cdot C_{lk}[m'] \cdot a_k\right\}$$

wherein

$\hat{a}_{lq}^{*}$ is an estimate of a_{lq}^{*}, which represents a complex conjugate of one multipath amplitude component of the l^{th} user,

$a_{kq'}$ is one multipath amplitude component associated with the k^{th} user, and

C denotes the aforesaid C matrix.

19. The method of claim 18, wherein the step of generating detection statistics comprises computing the detection statistics in accord with the relation:

$$y_l[m] = r_{ll}[0]b_l[m] + \sum_{k=1}^{K_v} r_{lk}[-1]b_k[m+1] + \sum_{k=1}^{K_v}\left[r_{lk}[0] - r_{ll}[0]\delta_{lk}\right]b_k[m] + \sum_{k=1}^{K_v} r_{lk}[1]b_k[m-1] + \eta_l[m]$$

wherein

$y_l[m]$ represents detection statistic for the mth symbol transmitted by the lth user,

$r_{ll}[0]b_l[m]$ represents a signal of interest, and

remaining terms of the relations represent Multiple Access Interference (MAI) and noise.

20. The method of claim 19, wherein the step of generating symbol estimates comprises computing the estimates in accord with the relation:

$$\hat{b}_l[m] = sign\left\{ y_l[m] - \sum_{k=1}^{K_v} r_{lk}[-1]\hat{b}_k[m+1] - \sum_{k=1}^{K_v}[r_{lk}[0] - r_{ll}[0]\delta_{lk}]\hat{b}_k[m] - \sum_{k=1}^{K_v} r_{lk}[1]\hat{b}_k[m-1] \right\}$$

wherein

$\hat{b}_l[m]$ represents an estimate of the mth symbol transmitted by the lth user,

g is a pulse shape vector,

N_c is the number of samples per chip,

τ is a time lag, and

Γ represents the Γ matrix.